# Multi-band Coax Extender for In-building Digital Communication Systems

## Cross-Reference to Related Applications

This application claims priority to a provisional application filed February 7, 2001 with U.S. Serial No. 60/267,046. This application provides a way to boost the signal carrying capacity of a system to provide High Speed Data Communication Over Local Coaxial Cable as described in co-pending application 09/482,836 based on Provisional Application No. 60/115,646 filed January 13, 1999. This application claims priority to the '836 application and also claims priority to another application assigned to common assignee coaXmedia, Inc and its priority document. The title of the claimed application is Architecture and Method for Automated Distributed Gain Control for Internet Communications for MDUs and Hotels (Application No. 09/818,378 based on Provisional Application No. 60/193,855). The '855 application has the filing date of March 30, 2000.

For the convenience of the reader, applicant has added a number of topic headings to make the internal organization of this specification apparent and to facilitate location of certain discussions. These topic headings are merely convenient aids and not limitations on the text found within that particular topic.

In order to promote clarity in the description, common terminology for components is used. The use of a specific term for a component suitable for carrying out some purpose within the disclosed invention should be construed as including all technical equivalents which operate to achieve the same purpose, whether or not the internal operation of the named component and the alternative component use the same principles. The use of such specificity to provide clarity should not be misconstrued as limiting the scope of the disclosure to the named component unless the limitation is made explicit in the description or the claims that follow.

## *Background of the Invention*

### Technical Field

The present invention adds to the field of data communications. More particularly the invention is one of the ongoing improvements in the area of data communications addressing the use of tree and branch distribution systems for upstream and downstream data communication between a hub-server and a set of two or more client modems. Preferably, the client modems are adapted to allow a plug and play connection or other easy connection between a laptop and the tree and branch network. The tree and branch network is preferably connected to the Internet. Thus, the present invention can be used in a hotel or Multiple Dwelling Units (MDU's) or analogous buildings to allow plug and play access to the Internet over existing coax television networks. Note, the present invention is not limited to installations in a hotel or Multiple Dwelling Units (MDU's) or analogous buildings, these are examples of locations that can use the benefits of the present invention.

The '836 application describes a system that allows the connection of devices such as personal computers to special modems that connect to a legacy tree and branch coax network in a hotel, Multiple Dwelling Units (MDUs), or analogous building. The system described in the '836 application used two bands outside of the range used for cable TV. Thus, the system would have one frequency range for a downstream data channel and one frequency range for an upstream data channel. As this is a tree and branch network, all communications heading downstream must identify which modem device (or devices) are being addressed since all modem devices will receive the communication. Conversely, the communication from the many individual modem devices to the upstream end of the network must be controlled so that only one modem device is sending an upstream communication at any one time in order to avoid distortions to the upstream data resulting from more than one client modem transmitting on the same frequency at the same time ("bus contention"). The method of control used in the referenced applications is based on a polling and response model.

The present invention improves prior work by assignee coaXmedia, Inc. by providing a way to increase the capacity of the main feeder cables to carry communications to and from client modems.

In the preferred embodiment, the client modems are all mass-produced to operate at the same pair of upstream and downstream frequency bands.

The situation addressed by both the referenced applications and the current invention is shown generally in **FIGURE 1**.

## Environment

The previously described solution can be summarized by **FIGURE 1**. In **FIGURE 1**, the bandwidth between 50 MHz and 860 MHz **(108)** is allocated for downstream transmission of television signals. The band of 5MHz to 42 MHz **(104)** is used for the existing services that use upstream traffic such as pay-per-view. Much of the frequency band between 860 MHz and 900 MHz **(112)** is used for other applications such as cellular telephones. Due to the relatively high field-strength radiation of portable cellular handsets, it is prudent to avoid using frequencies close to those used for cellular telephones.

The legacy coax distribution networks have splitters and couplers that operate satisfactorily up to approximately 1 GHz (1000 MHz). Thus, the '836 application and the '378 application suggested having a downstream frequency for data and an upstream frequency for data, both in the band between 900 MHz and 1000 MHz. In **FIGURE 1**, the upstream frequency is shown at 915 MHz **(116)** and the downstream frequency is shown at 980 MHz **(120)**. A single pair of upstream and downstream frequencies was thought sufficient to serve the statistical two-way Internet access needs of fifty to one-hundred users or client modems.

The '378 application taught that additional downstream spectra can be allocated in bands between 1 GHz and about 1.6 GHz provided that existing components are replaced with components that work adequately in this frequency band. This solution would require a means for the client modem to recognize a request to switch from the normal downstream channel of 980 MHz to the high frequency channel. Thus, in addition of the cost to upgrade the components of the legacy coax network, there would be a need to provide more expensive client modems that can operate on multiple downstream frequencies.

**Problem being addressed**

As illustrated in **FIGURE 2**, larger Multi-Dwelling Unit (MDU) in-building coax cable TV distribution systems commonly have many more than fifty coax receptacles. These larger distribution systems normally have a mix of local services **604** in addition to the TV channels. In a hotel the local services might include a digital video server, check-out information and information about the hotel restaurants.

The local services **604** and cable television channels **608** would be combined at element **612** and amplified by central location amplifier **620** before the feeder cable **624** (sometimes called a coax riser).

An even larger system might include one or more central location splitters **630** to feed additional pairs of an amplifier **634** and another long feeder cable **638**. To avoid clutter in the drawing, the local distribution networks connected to long feeder cable **638** are not shown. These distribution systems require intermediate amplifiers **650** to boost the signal levels that have been attenuated by coax cable, splitter and directional tap losses, in order that sufficient signal levels be provided to television sets and/or other entertainment equipment. These intermediate amplifiers **650** are distributed within an MDU at some distance from the central feed point to the building which may provide services from CATV, TV broadcast antenna or via means such as fiber optics. These intermediate amplifiers **650** normally carry TV channel signals in one direction only, usually at frequencies in the range 50 MHz to 750 MHz. In some cases these amplifiers are equipped with a reverse direction amplifier that can carry signals in the frequency range 5 MHz to 42 MHz. The reverse channel is sometimes used to carry command signals for requesting pay-per-view (PPV) television services or, with increasing frequency, the upstream channel of a cable modem used for Internet access.

When the TV coax distribution system is utilized to carry data outside of the CATV frequency band, there is a need to provide bypass amplifiers for each signal direction, connected to the coax cables via frequency selective diplexers. Thus, when implementing a system to carry data on an existing cable television network, there is a need for circuitry such as shown in **FIGURE 3** to boost the data signals.

**FIGURE 3** operates without interference to the operation of existing CATV line extender amplifier **650**. The amplifier **650** is isolated by a pair of low-pass filters **654** in diplexers **660**. A high frequency bypass around the existing amplifier **650** is provided by a pair of high-pass filters **658**. The bypass is split into a downstream channel and an upstream channel by splitters **664**. The downstream channel and the upstream channel are isolated from one another by shielding **668**.

For a system using 980 MHz as the downstream frequency and 915 MHz as the upstream frequency, the downstream channel is comprised of a 980 MHz bandpass filter **672**, a variable attenuator **676**, an amplifier **680**, and a 915 MHz band-stop filter **684**. The upstream channel is comprised of a 915 MHz bandpass filter **688**, a variable attenuator **676**, an amplifier **692**, and a 980 MHz band-stop filter **696**.

When too many users share the data distribution system, there may be insufficient capacity. Insufficient capacity can lead to service degradation in the form of lost or delayed data packets. The number of users that is "too many" is a function of the type of data needs for the individual users. How many users are "too many" users? It depends on whether the users are likely to be connected at the same time, the need to receive or transfer large amounts of data and the sensitivity of the applications to delays in receiving data packets. As the amount of data communicated to a single connected user increases with the evolution towards multimedia, video conferencing, and other data intensive applications, the number of users that can be supported by the data networks will drop. Low latency applications such as video conferencing or voice over IP (Internet Protocol) exacerbate the problem.

While it may seem attractive to simply use additional frequencies for the upstream and or the downstream channel, this is not an attractive solution.

There are several advantages to having a set of client modems that are tuned to receive a single downstream frequency and to transmit on a single upstream frequency. For example, manufacturing and set up costs are reduced if there is not the need to provide modems that can be tuned to operate on a range of receive or transmit frequencies.

Even if a designer was willing to forego the advantages of using the same pair of transmit and receive frequencies for an entire set of client modems, there are practical limits to the

number of frequency bands available above 900 MHz. One problem is that approximately 1 GHz is an effective frequency ceiling. This limitation comes from the reality that the splitters, directional taps, connectors and sometimes the coax cable itself in the distal portions of the coax distribution tree and branch network frequently perform poorly at frequencies much beyond 1 GHz.

Using several frequency channels in the spectrum above 900 MHz and below 1 GHz has its own problems. One problem is that adding additional channels will result in increased total signal power. This additional signal power will then increase the risk of signal overload in the active elements of the network. The overload can adversely impact the delivery of TV services. An additional problem is that adding more channels will increase the complexity of filters required to separate the individual channels.

Fortunately, the main (feeder) coax distribution cables (**624**, **638**) connecting TV signals between the feed point to the building and the distributed "booster" amplifiers **650** are usually able to carry frequencies well above 1 GHz, as these feeder cables do not usually include directional taps or splitters. Even if there are a few taps or splitters before the booster amplifiers it will be easy to replace or upgrade the components. It will be easy because even if there are taps or splitters before the booster amplifiers, there will only be a few and they are easily accessible. This is in sharp contrast to the situation after the booster amplifiers where there are many taps and most are difficult to access.

## BRIEF SUMMARY OF DISCLOSURE

The present invention solves the prior art limitations by utilizing a two-stage system. In the preferred embodiment, the feeder cable stage takes advantage of the capacity of the feeder cable to carry multiple bands of data in the frequency spectrum above 1 GHz. The local stage converts these bands of data into corresponding bands in the frequency range 900 MHz to 1 GHz, at the TV "booster" amplifier locations, and amplifies these downstream communications for onward transmission to end users connected in groups to individual local tree and branch networks in the TV coax distribution system. Likewise, at least some of the upstream communications are shifted to a frequency above 1 GHz for upstream transmission on the feeder

cable. The solution of the present invention offers significantly higher data capacity in a system in which all data interface "modems" can be identical and without complex tuning functions. Thus, the modems for use at the end user termination points of the tree and branch network can be mass produced and preset for given upstream and downstream channels as the many upstream and downstream bands are converted into standard upstream and downstream frequency channels for the local stage of the distribution. The modems can be used interchangeably on several different local tree and branch networks.

Optionally, one set of upstream and downstream communications can travel on the feeder cable at the frequencies used by the client modems so that no frequency shifting is required for this fraction of the communications. While using the same frequencies for all client modems may be desirable for administrative or economic reasons, the present invention is not limited to networks where all client modems operate solely on one pair of upstream and downstream frequencies. Alternative frequencies bands, other than above 1 GHz, are suggested in the discussion of alternative embodiments.

## BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows the frequency bands used in the related applications to convey data upstream (**116**) and downstream (**120**) over a legacy tree and branch distribution network for cable television.

Figure 2 illustrates the relationship between the feeder cables (**624** and **638**) with local coax distribution networks **762**, **766**, **768**, and **770**.

Figure 3 illustrates the components in a line extender used to provide amplified signals for the data sent over the legacy tree and branch distribution networks.

Figure 4 illustrates one embodiment of the present invention using three different downstream frequencies over the feeder cable **624** but only one upstream frequency over the feeder cable **624**.

Figure 5 illustrates another embodiment of the present invention using three different downstream frequencies over the feeder cable **624** and three different upstream frequencies over the feeder cable **624**.

## DETAILED DESCRIPTION OF THE DISCLOSED EMBODIMENTS

### Overview of Figures 4 and 5

FIGURES 4 and 5 show two principal embodiments of the present invention. Both embodiments are shown on a combination of a Figure A that shows the equipment upstream of the feeder cable **624** and a Figure B that shows the equipment downstream of the feeder cable **624**.

Both embodiments have one central system to feed one or more feeder cables (**624** or **638**) and ultimately a number of local networks. In the preferred embodiment, each local network would use standard client modems with pre-set frequencies for transmit and receive.

**FIGURE 4** differs from FIGURE 5 in that FIGURE 4 anticipates a situation where one upstream frequency is adequate for the entire set of client modems but the downstream data requirements exceed the bandwidth of a single downstream frequency. In both FIGURE 4 and **FIGURE 5**, the system uses several frequencies to carry downstream transmissions on the feeder cable before conversion to the standard downstream frequency for transmission on the parallel local networks. The embodiment of **FIGURE 4** will be suitable for many situations with much more information sent downstream to client modems than sent upstream from the client modems. Web browsing is one example of an application with this downstream/upstream imbalance. Much more downstream capacity is needed to convey the data necessary to construct a web page than is necessary to communicate upstream the simple request to display that web page. An additional load on downstream capacity is Value Added (VA) services, such as local digital video services, that require broadband capacity. The combination of downstream data from the Internet service provider with the bandwidth intensive Value Added services will frequently lead to a need for more downstream capacity than upstream capacity. In many situations, there will

be too much downstream traffic for the existing feeder cables to carry it all on one downstream frequency in the 900 MHz to 1 GHz spectrum.

The system illustrated in **FIGURE 5** is like **FIGURE 4** in that the illustrated system has multiple downstream frequencies for the feeder cable. The embodiment shown in **FIGURE 5** differs from **FIGURE 4** in that it has more than one upstream frequency for the upstream travel through the feeder cable. **FIGURE 5** is adapted to work in situations where both the upstream and downstream traffic exceed the bandwidth for a single frequency on the feeder cable. Email or voice over IP are examples of applications that have a more even distribution between upstream and downstream data.

## Details of Figure 4

The cable television signals from coax **608** connected to the CATV service drop are amplified at amplifier **312** before reaching the low-frequency leg of diplexer **316**.

The high-frequency leg of diplexer **316** receives data from Internet access, local Value Added services (if any), and from the digital video server **712** (if any). More specifically, the connection to the Internet **704** can be split from the CATV service drop cable **608**, or come through another communication route such as fiber, cable modem, or wireless.

In **FIGURE 4A**, the functions of a central hub are allocated across a set of components. The conversions from the Internet protocol to local network protocol occur in a central server **708**. Typically, the conversions will be from Ethernet to PPPoE (PPP over Ethernet) in the downstream direction and the reverse for upstream transmission. Optionally, other local value added services can be administered in central server **708**. Part of the local Value Added services can include a request for delivery of content from digital video server **712**.

The downstream data including data from the digital video server **712** pass to a router **716** that distributes the data to a set of two or more central modems (**720**, **722**, and **724**). As this embodiment is set for a system with relatively small amounts of upstream traffic, only one central modem **720** is used to receive upstream traffic. In the example shown in **FIGURE 4A**, the downstream traffic is carried to one set of client modems on feeder cable frequency 980 MHz. Downstream traffic to another set of client modems is carried on feeder

cable frequency 1.05 GHz to take advantage of the capacity of the feeder cable to carry frequencies above one gigahertz. Downstream traffic to yet another set of client modems is carried on feeder cable frequency 1.10 GHz.

In the preferred embodiment, there would be an additional modem for each additional feeder cable frequency used for downstream traffic. As will be evident in the description of **FIGURE 4B**, the use of the downstream frequency used by the client modems as one of the feeder cable frequencies reduces the amount of components used in **FIGURE 4B**. Alternatively, the system could be set up to use downstream feeder cable frequencies above one gigahertz for all central modems and then convert all the downstream traffic to the downstream frequency used by the client modems.

The upstream traffic from all the client modems is transmitted on the single upstream feeder cable frequency of 915 MHz which is the same frequency used by the client modems. The coax cables from each of the three central modems are connected to combiner **734** which is connected to the high-frequency leg of diplexer **316**.

**FIGURE 4B** illustrates a multi-band coax extender for use with **FIGURE 4A**. As an overview, the multi-band coax extender receives each of the three downstream bands and, using local frequency synthesizers and mixer elements, converts two of the received bands into two separate streams having bands identical to the third spectrum carried downstream on the main feeder. Each of these streams are then introduced, using spectral diplexers, into separate coax cable branches which may feed perhaps fifty or more client modems (such as the coaXmedia SandDollar™ client modem). In the upstream direction, using directional taps, same-spectrum signals from each of the separate coax cable branches are combined together, filtered to remove out-of-band noise, and amplified prior to insertion, as an upstream signal, onto the feeder cable **624** and back to the central modem **720** having an upstream receiver.

The system as described generally above is implemented in one embodiment with the following details shown in **FIGURE 4B**. Starting at the distal end of feeder cable **624** as shown in **FIGURE 4B**, the feeder cable **624** feeds diplexer **750**. In one preferred embodiment, diplexer **750** is set with low pass from DC to 865 MHz and with high pass set to 905 MHz and above. The low-frequency leg of the diplexer **750** feeds the input to the television amplifier **650**,

which in turn feeds diplexers **754**, **756**, and **758**. Each of the diplexers (**754**, **756**, and **758**) feeds a local coax distribution network **762**, **766**, or **770**.

Depending on the anticipated loading, the distribution networks service approximately fifty end users. The distribution network terminates with equipment such as set forth in block **400**. The details for one of the many blocks are shown on **FIGURE 4B**. The actual layout of components within block **400** is not important for purposes of this invention and the sample given should not be interpreted as a limitation of the scope of the invention. For purposes of illustration, the components within block **400** are as follows:

Within cluster **400**, a client modem **408** connects to the high-pass port on diplexer **406**. Diplexer **406** is connected to the coax receptacle **404**. Sample values for the downstream legs of the diplexer **406** are LP 5MHz to 860MHz and HP 900 MHz to 1 GHz. A conventional TV coax cable **412** connects a television **416** to the low-pass port on the diplexer **406**. The client modem **408** is shown as a sand dollar in deference to the assignee's trademarked name for assignee's client modem.

The user may connect a downstream device **420** to the data cord of client modem **408**. The user's downstream device **420** could be a personal computer ("PC"). While the downstream device **420** is likely to be either a desktop or laptop personal computer, it could be some other device capable of interfacing with an external source of digital data. One such example is the range of devices known as PDAs ("Personal Digital Assistants"). Thus, the present invention allows for communication between the downstream device **420** and the Internet through substantial use of existing infrastructure used to deliver cable TV signals to user's television **416**.

Each of the three diplexers (**754**, **756**, and **758**) receives downstream transmissions at 980 MHz and upstream transmissions at 915 MHz. While the aggregate downstream traffic for all three local coax distribution networks (**762**, **766**, and **770**) is too much to be carried on one frequency on the feeder cable **624**, there is no problem having all the downstream traffic on the same frequency once it is divided among the three parallel local networks.

The components in block **800** handle the conversion from three feeder cable frequencies to three parallel local networks. The downstream path starts with diplexer **750** upstream of amplifier **650**. The high-frequency leg of the diplexer **750** feeds splitter **804**. The downstream

path continues from the splitter **804** to amplifier **808**. The portion of the downstream traffic at 980 MHz passes through a band pass filter **812** set at 980 MHz (passing plus or minus 20 MHz – as do band pass filters **836** and **852**). Since 980 MHz is the standard frequency used by the client modems **408**, no conversion is necessary and the downstream traffic passes through the directional tap **816** to the high-frequency leg of diplexer **754** on route to local coax distribution network **762**.

In parallel with the path for downstream traffic to local coax distribution network **762**, there is a path for downstream traffic to local coax distribution network **766**. Downstream traffic for network **766** at feeder cable frequency 1.05 GHz exits the amplifier **808** and passes through high-pass filter **820** set to pass frequencies above 1.02 GHz. The high-pass filter **820** is used to prevent residual lower-band spectrum, which could potentially pass directly through either of the mixers (**832** or **848**), from interfering with similar spectrum in the 980 MHz range created by the down-conversion from higher spectrum bands of the downstream traffic for local coax distribution networks **756** or **758**.

Through use of oscillator **824**, synthesizer **828**, and mixer **832**, the downstream traffic is shifted to 980 MHz and passes through band pass filter **836** and directional tap **840** to reach the high-frequency leg of diplexer **756**. (Typical synthesizer output values would be 70 MHz or 2.03 GHz.) Diplexer **756** is connected to local distribution network **766**.

In a similar way, the downstream traffic for local coax distribution network **770** travels on coax feeder **624** at 1.10 GHz. The downstream traffic passes through high-pass filter **820**. Through use of oscillator **824**, synthesizer **844** and mixer **848**, the downstream transmission is shifted to 980 MHz and passes through band pass filter **852** and directional tap **856** to reach the high-frequency leg of diplexer **758**. (Typical synthesizer output values would be 120 MHz or 2.08 GHz.) Diplexer **758** is connected to local distribution network **770**.

As mentioned in connection with **FIGURE 4A**, the downstream traffic to local coax distribution network **762** could have been carried on the feeder cable **624** on a frequency other than the standard downstream frequency (980 MHz) used by the client modems **408**. This choice would require an additional synthesizer and mixer along with adjustments to the filter scheme.

The upstream traffic from the three local coax distribution networks is sent on standard frequency 915 MHz. The upstream path is from diplexers **754**, **756**, and **758** through directional taps **816**, **840**, and **856** to combiner **860**.

The combined upstream traffic passes through band pass filter **864** set for 915MHz (plus or minus 10 MHz). The upstream traffic is amplified at **868** and passes through splitter **804** to the high-frequency leg of diplexer **750** to feeder cable **624**.

**FIGURE 4** illustrates a system with three modem pairs servicing three local distribution networks. In practice, any number of modem pairs may be combined in this matter, taking into consideration the required downstream capacity. Two small local distribution networks can share one pair of a modem and a feeder cable frequency. The present invention can be used in situations with two or more local coax distribution networks.

## Details of Figure 5

**FIGURE 5A** illustrates a similar arrangement to that shown in **FIGURE 4A** with the exception that each central modems (**720**, **726** and **728**) includes an upstream receiver. Each receiver is tuned to a different coax feeder upstream frequency. The advantage of this arrangement is the multiplication of upstream capacity. The specific frequency bands shown are by way of example only as the principle may be applied independently of frequencies or spectrum used. As with the downstream frequencies, there is a slight advantage to using the standard transmit frequency for the client modems **408** as one of the coax feeder upstream frequencies. However, it is not required that one of the coax feeder upstream frequencies be the same as the standard transmit frequency for the client modems **408**.

**FIGURE 5B** illustrates a similar arrangement to that shown in **FIGURE 4B** with exception that the same-spectrum upstream bands from two of the separate local coax distribution networks are frequency-shifted before being combined for transmission in an upstream direction on the main coax feeder **624**. In this example, the downstream traffic at splitter **804** is carried on frequencies 980 MHz, 1.11 GHz, and 1.24 GHz. The upstream traffic at splitter **804** is carried on frequencies 915 MHz, 1.045 GHz, and 1.175 GHz.

More specifically, in the preferred embodiment, the upstream communications from local coax distribution network **762** passes through diplexer **754**, directional tap **816**, and band pass filter **872**, to combiner **860** without modification of the upstream frequency of 915 MHz. (Typical values for band pass filters **872, 876,** and **880** are 915 +/- 20 MHz)

The upstream traffic from local coax distribution network **766** is also at 915 MHz but after passing through diplexer **756**, directional tap **840**, and band pass filter **876**, the upstream traffic is shifted to 1045 MHz by mixer **884** using synthesizer **838** output at 130 MHz. The shifted upstream traffic passes through band pass filter **892** set for 1045MHz +/- 20 MHz.

Similarly, the upstream traffic from local coax distribution network **770** also starts at 915 MHz. After passing through diplexer **758**, directional tap **856**, and band pass filter **880**, the upstream traffic is shifted to 1075 MHz by mixer **888** using synthesizer **844** output at 260 MHz. The shifted upstream traffic passes through band pass filter **896** set for 1075MHz +/- 20 MHz.

## Alternative Embodiments

In the example shown in **FIGURE 5**, a single heterodyne frequency source, provided by a synthesizer, is used to frequency shift both a downstream and an upstream signal. Thus, the amount of frequency shifting for both directions of transmission will be identical. Alternatively, separate heterodyne frequencies may be employed, thus enabling a more flexible frequency plan.

The system as set forth on **FIGURES 5A** and **5B** uses 915 MHz for upstream communication and 980 MHz for downstream communication in the local coax distribution networks (**762**, **766**, and **770**). As shown in **FIGURE 5B**, one of the pairs of frequencies transmitted on the feeder cable **624** is 915 MHz and 980 MHz, which is used without frequency shifting by one of the local coax distribution networks **762**. This eliminates the need for an additional set of components to frequency shift these signals. While this is advantageous, it is not required and all of the bands may be frequency shifted without deviating from the scope of the present invention.

The band-pass filters included in **FIGURE 5B** may be conveniently and economically created using printed circuit board stripline elements. Other forms of filter, such as ceramic or surface acoustic wave types may alternatively be employed.

The solution employed could have multiple local coax distribution networks using the same upstream or downstream frequency over the feeder cable **624** providing that the aggregate traffic on the feeder does not exceed its carrying capacity for a given frequency. Thus, several local coax distribution networks may use the same feeder cable frequencies as are used in the local coax distribution network. One or more of the other local coax distribution networks would shift one or both of the communication frequencies to add to the carrying capacity of the feeder cable **624**.

The method described may be used in digital transmission systems using any form of modulation, or different forms of modulation on any portion of the coax distribution system.

The title and the disclosed embodiments of the present invention are given in the context of data communication using legacy cable television coax tree and branch networks. The frequencies chosen for the upstream and downstream communication reflect this environment. Note that one of skill in the art could select other frequencies or modulation schemes to implement this invention, especially in any tree and branch network that is not a coax network for use in distributing cable television signals, or in a tree and branch network that does not use coax.

When used in connection with data communication using legacy cable television coax tree and branch networks, the preferred embodiment uses frequencies on the feeder cable above the useful frequency range of the local distribution networks (typically frequencies above 1.0 GHz). Those of skill in the art could use the teachings of this invention to use additional carrier frequencies on the feeder cable to increase the bandwidth of the feeder cable through use of frequencies below 1.0 GHz. Generally, there are surmountable obstacles in using these other frequencies. The band of 5 to 42 MHz could be used, especially for an extra feeder cable downstream frequency, but this band is subject to a variety of uses that will change over time.

The frequency band set aside for television channels extends up to 860 MHz. Many systems do not use the frequency band from approximately 750 MHz to 860 MHz. This bandwidth could be used for additional feeder cable frequencies. A downside of using this band of frequencies is that cable television providers in some zones may already be using the 750 MHz to 860 MHz band, so this solution may not be universally applied. Another possible

place to put additional feeder cable frequencies is in unused television channels within the band of frequencies used for television channels. Depending on the modulation and filter equipment used to convey the feeder cable frequencies, it may be necessary to find several contiguous unused television channels in order to carry one feeder cable frequency. A problem with using unused channels is that cable television providers rearrange the channels that are used to convey the television signals from time to time. A rearrangement by the cable television provider might cause a conflict with the plan to have extra feeder cable frequencies when unused television channels become active television channels, thus triggering a need to adjust the equipment to use a different frequency.

The frequency band of approximately 900 MHz to 1.0 GHz is yet another possible band to carry additional feeder cable frequencies. As noted above, there would be possible problems from aggregate signal power and the need for a more rigorous filter scheme in order to add additional feeder cable frequencies to this band as the preferred embodiment already uses 915 MHz and 980 MHz. While these factors point towards using the band above 1.0 GHz, the band between 900 MHz and 1.0 GHz could carry three or more feeder cable frequencies rather than two feeder cable frequencies.

Those skilled in the art will recognize that the methods and apparatus of the present invention have many applications and that the present invention is not limited to the specific examples given to promote understanding of the present invention. Moreover, the scope of the present invention covers the range of variations, modifications, and substitutes for the system components described herein, as would be known to those of skill in the art.

The legal limitations of the scope of the claimed invention are set forth in the claims that follow and extend to cover their legal equivalents. Those unfamiliar with the legal tests for equivalency should consult a person registered to practice before the patent authority which granted this patent such as the United States Patent and Trademark Office or its counterpart.